COGNITION AND DESIGN

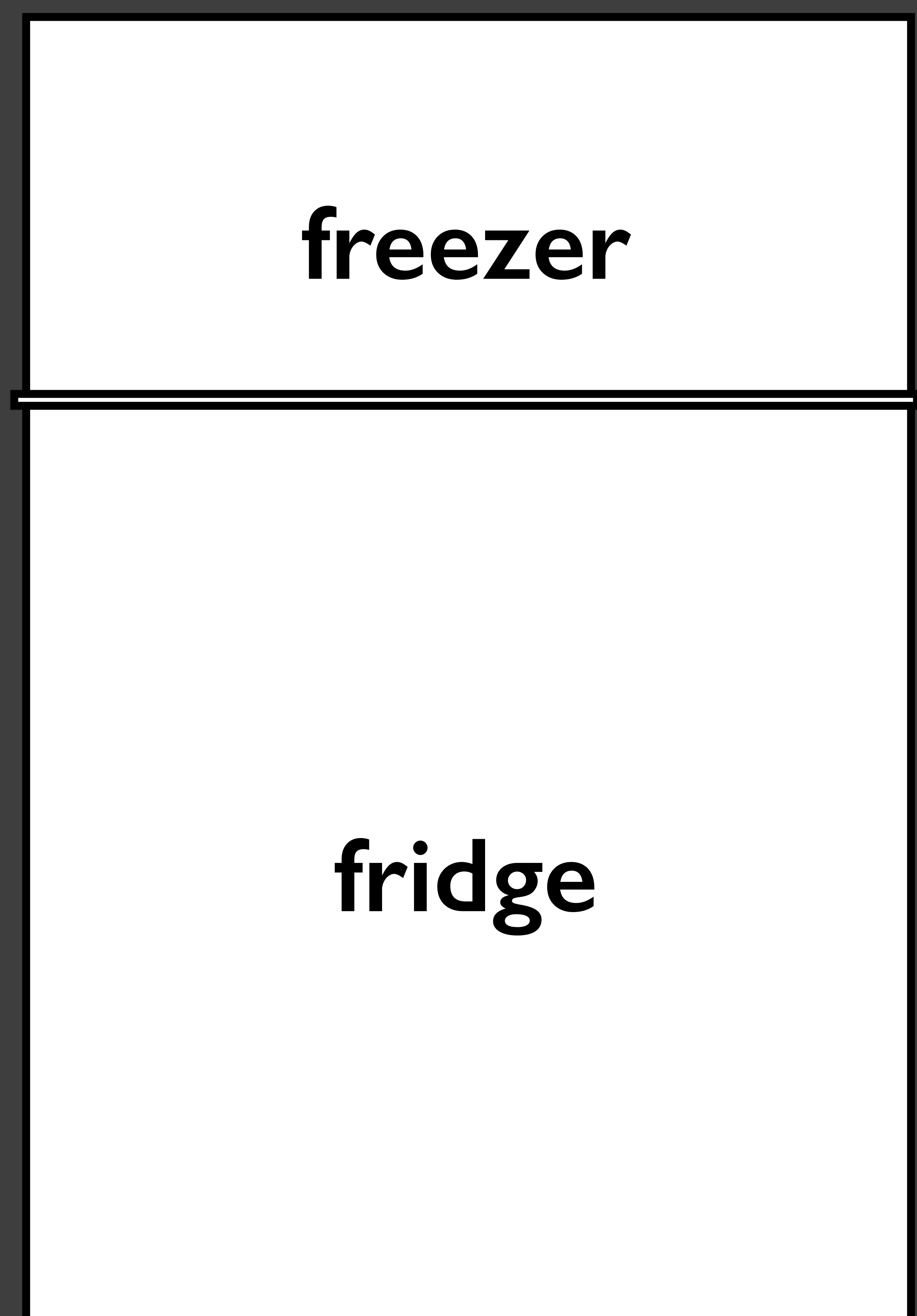
Scott Klemmer and Michael Bernstein

Today: how user interfaces connect with cognitive strengths

- Mental models
- Gulfs of evaluation and execution
- Direct manipulation
- Externalized cognition

Mental models

Consider this refrigerator...



problem:

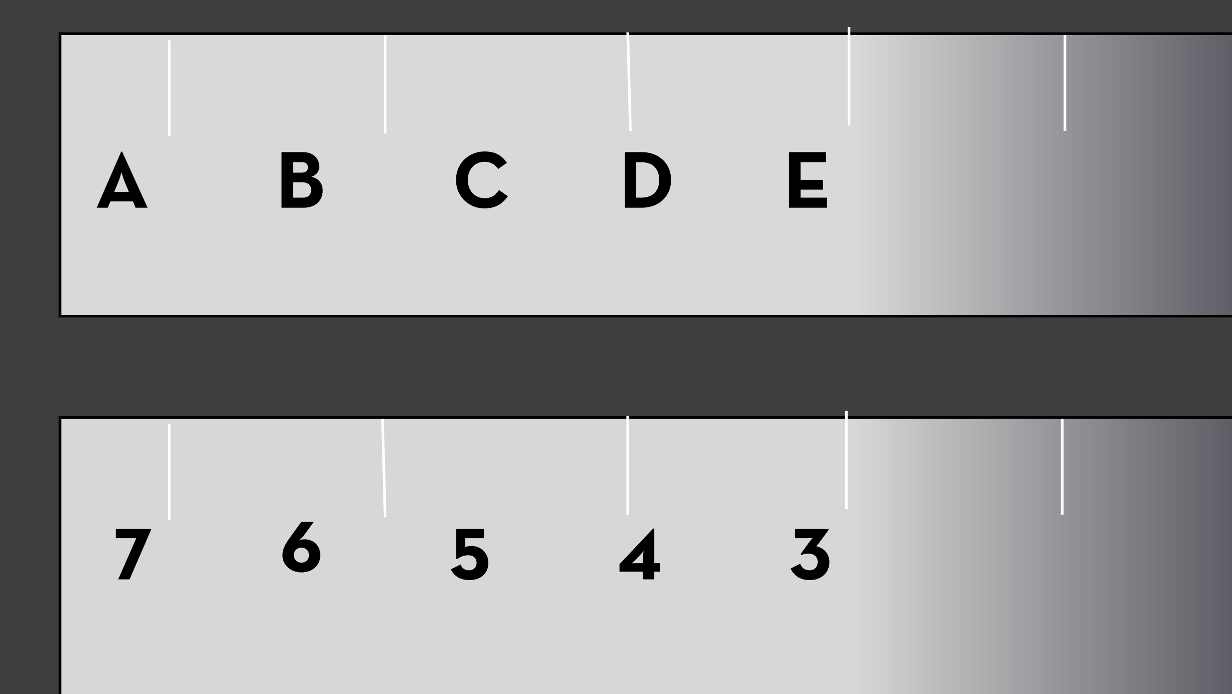
freezer too cold, but fresh food just right

Concept from: Don Norman, The Design of Everyday Things.

The refrigerator has two dials

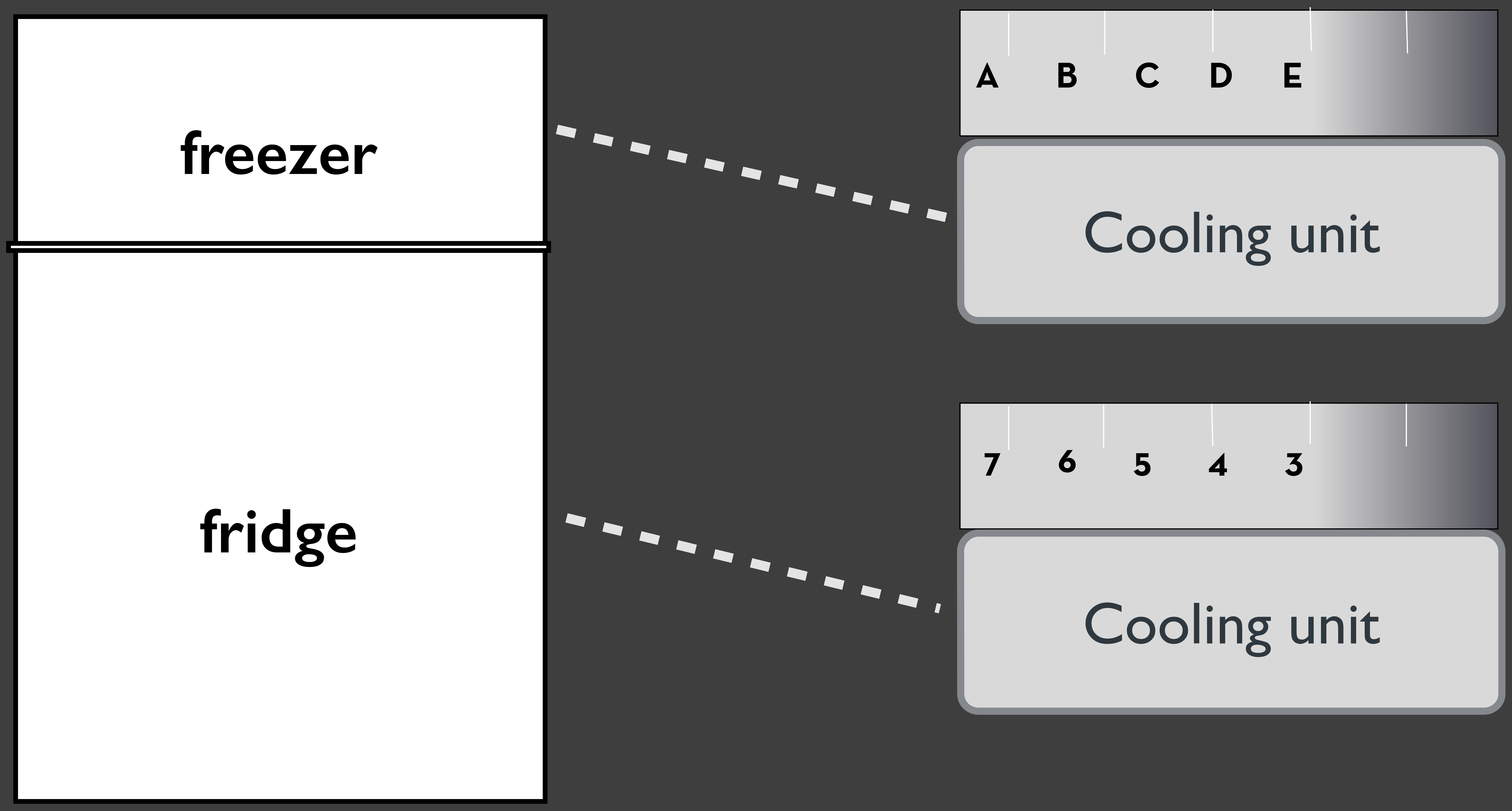
How does the system work?

Normal Setting	C and 4
Colder Fresh Food	C and 5-6
Coldest Fresh Food	B and 7
Colder Freezer	D and 6-7
Warmer Fresh Food	C and 3-1
OFF (both)	OFF (both) 0



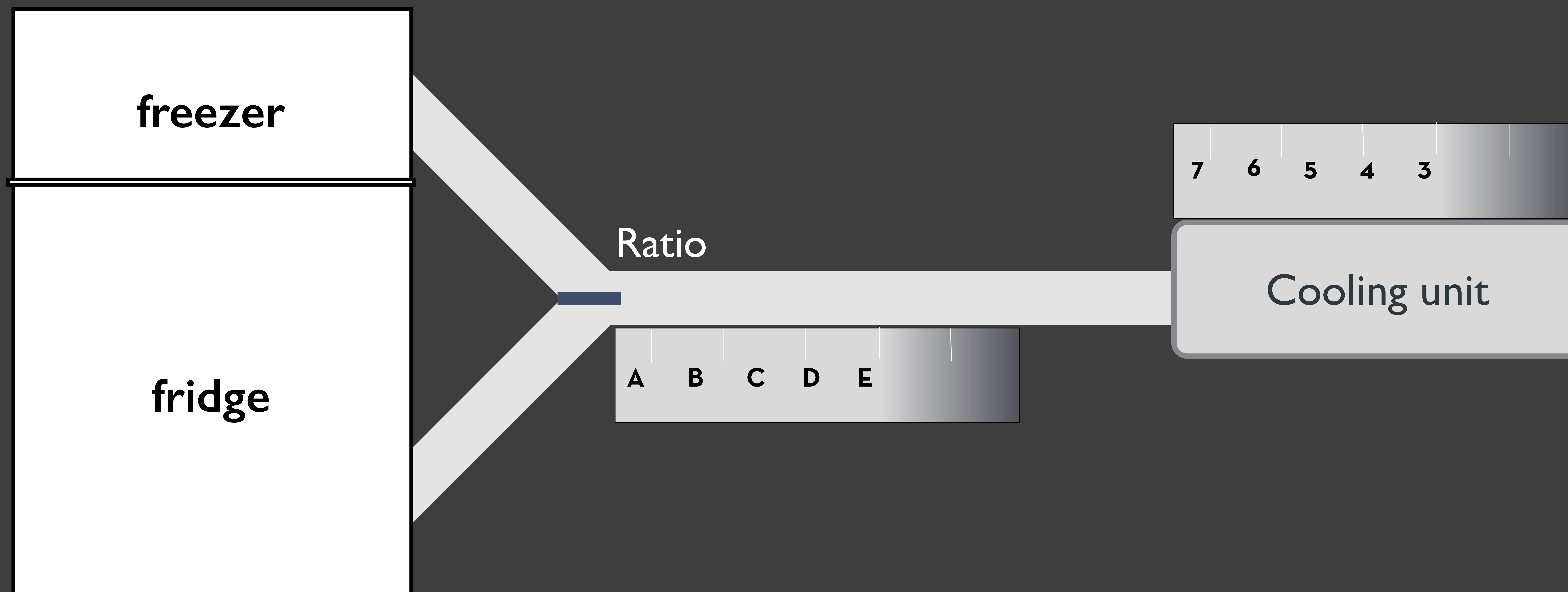
A likely model...

i.e., independent controls



Actual model

Now can you fix the problem?



Mental model

- **User’s thought process about how something works in the real world**
- Correct mental model: one dial controls the cooling unit, the other controls the ratio of cold air to fridge and freezer
- Incorrect mental model: two separate cooling units

Goal of design: instill the correct mental model

- If users have the correct understanding of a design, they can confidently take action
- Users develop their model through interaction with the system
- Designers begin with the correct mental model
- Often, the user's model != the designer's model

Conceptual Model Mismatch

- Mismatch between designer's & user's conceptual models leads to…
  - Slow performance
  - Errors
  - Frustration
  - …

Mental models arise from experience, metaphor, and analogical reasoning

- "A text processor is a typewriter"
- We have models (beliefs) about our own behavior, of others, of objects, software...
- Our models are incomplete, inconsistent, unstable in time, and often rife with superstition

JM Carroll, JR Olson, *Mental models in human-computer interaction: Research issues*, 1987

Slips

- Correct model but accidental execution

- e.g., trying to hit the save button but accidentally quitting
- e.g., accidentally shifting the car into Neutral

Mistakes

- Incorrect model

- e.g., looking for a save button in Google Docs
- e.g., not using the clutch in a manual transmission car

Butterfly Ballot

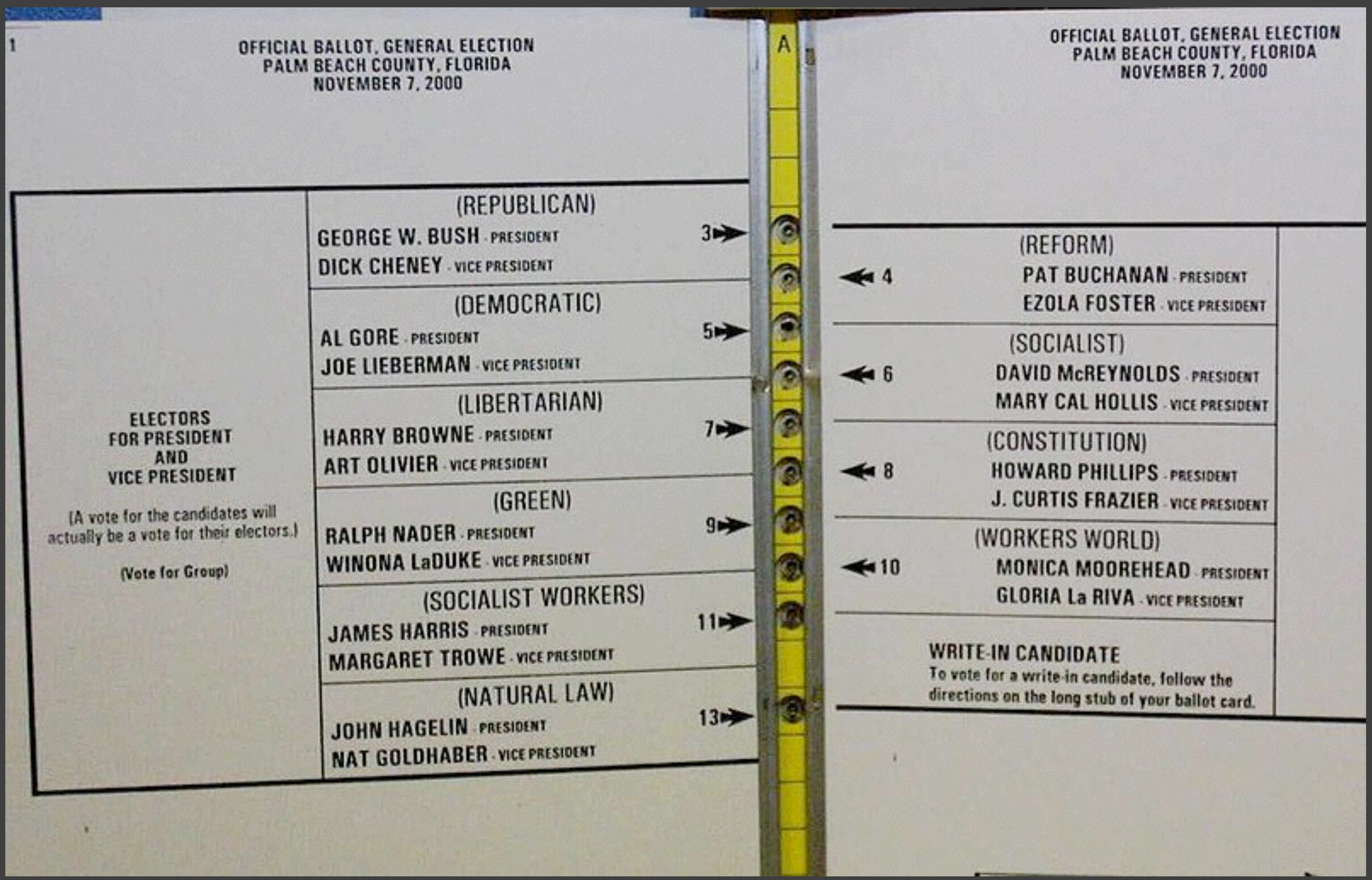


Image Courtesy Wikipedia: http://en.wikipedia.org/wiki/File:Butterfly_large.jpg

Clear mapping between control + function

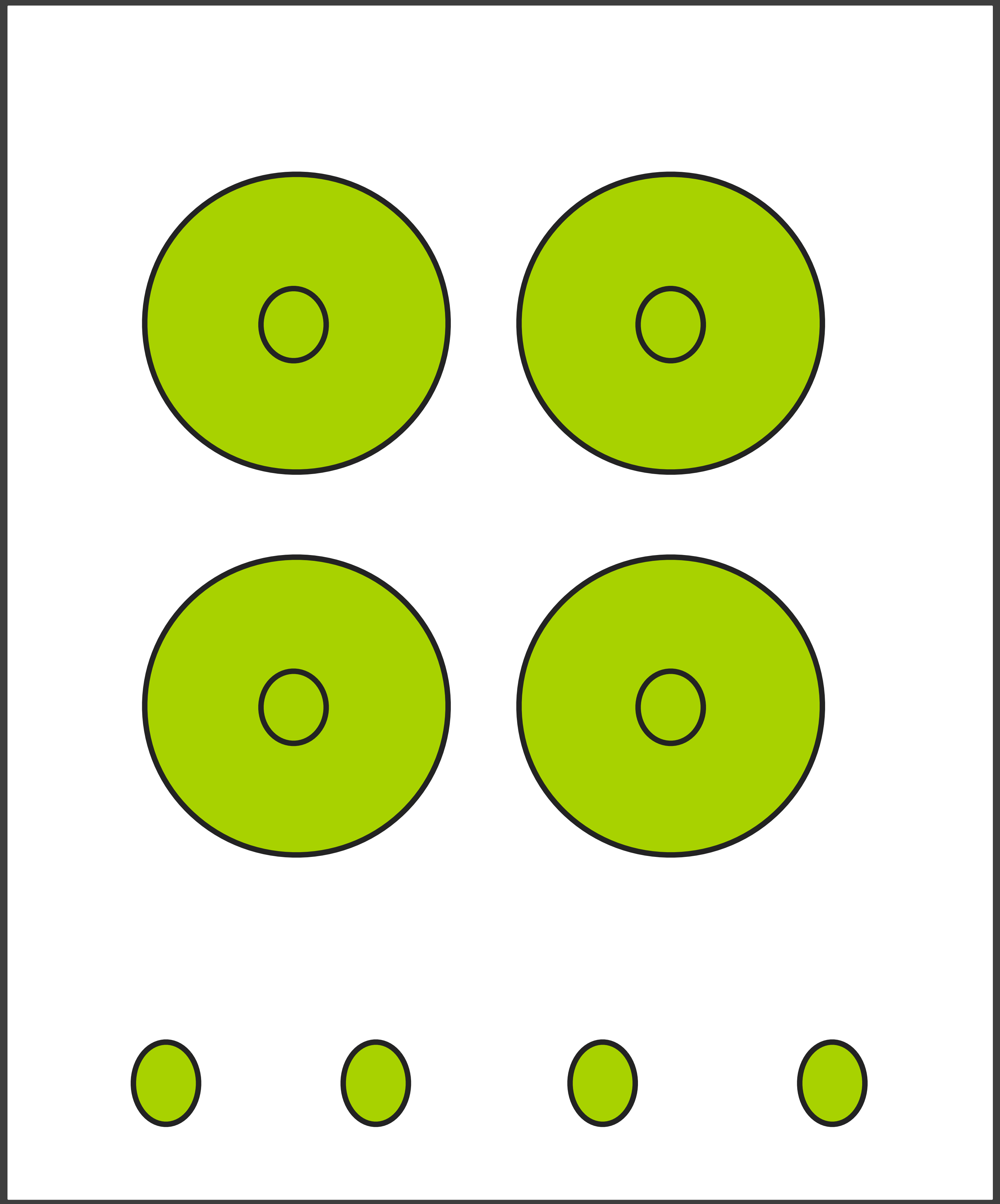
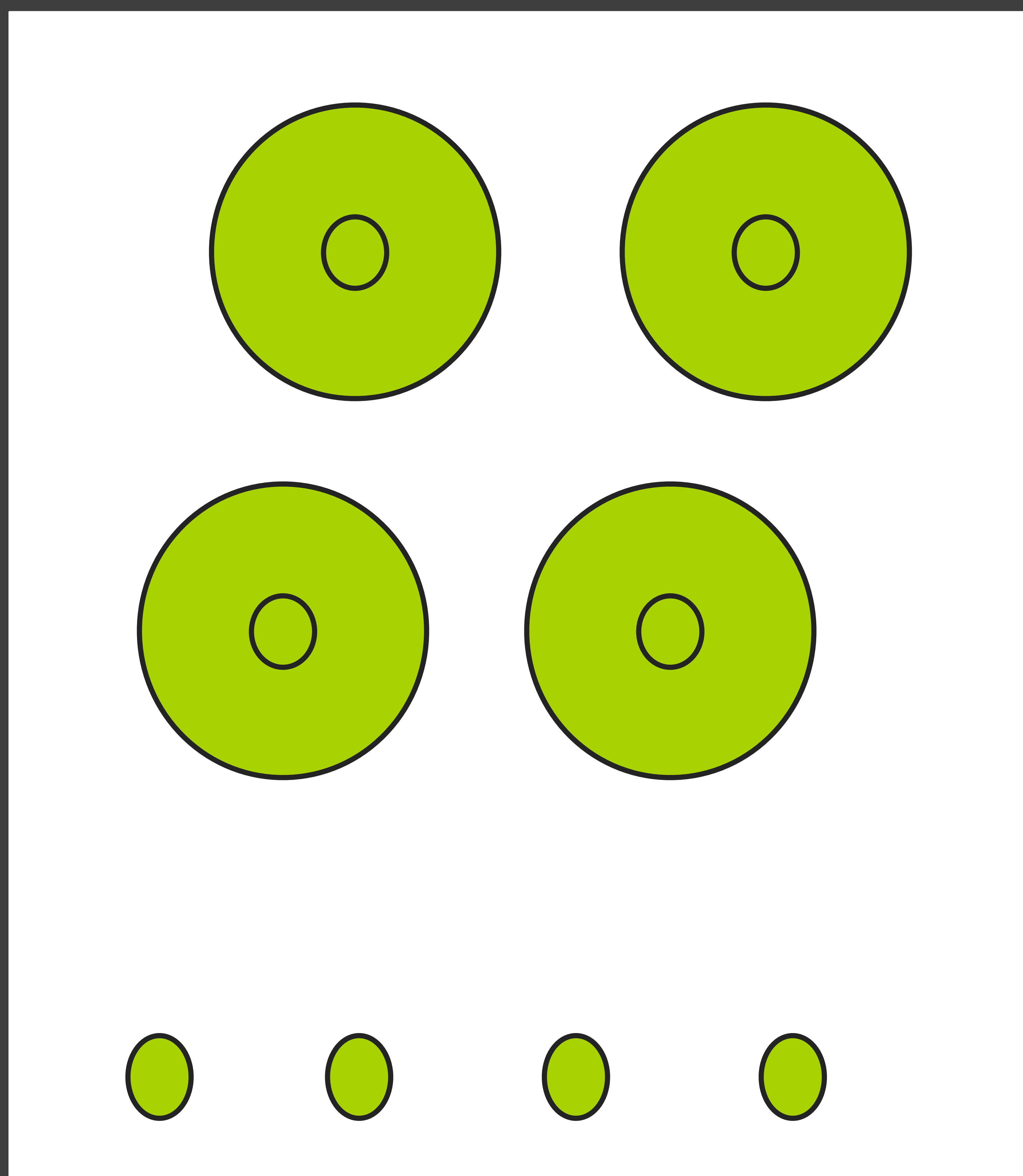
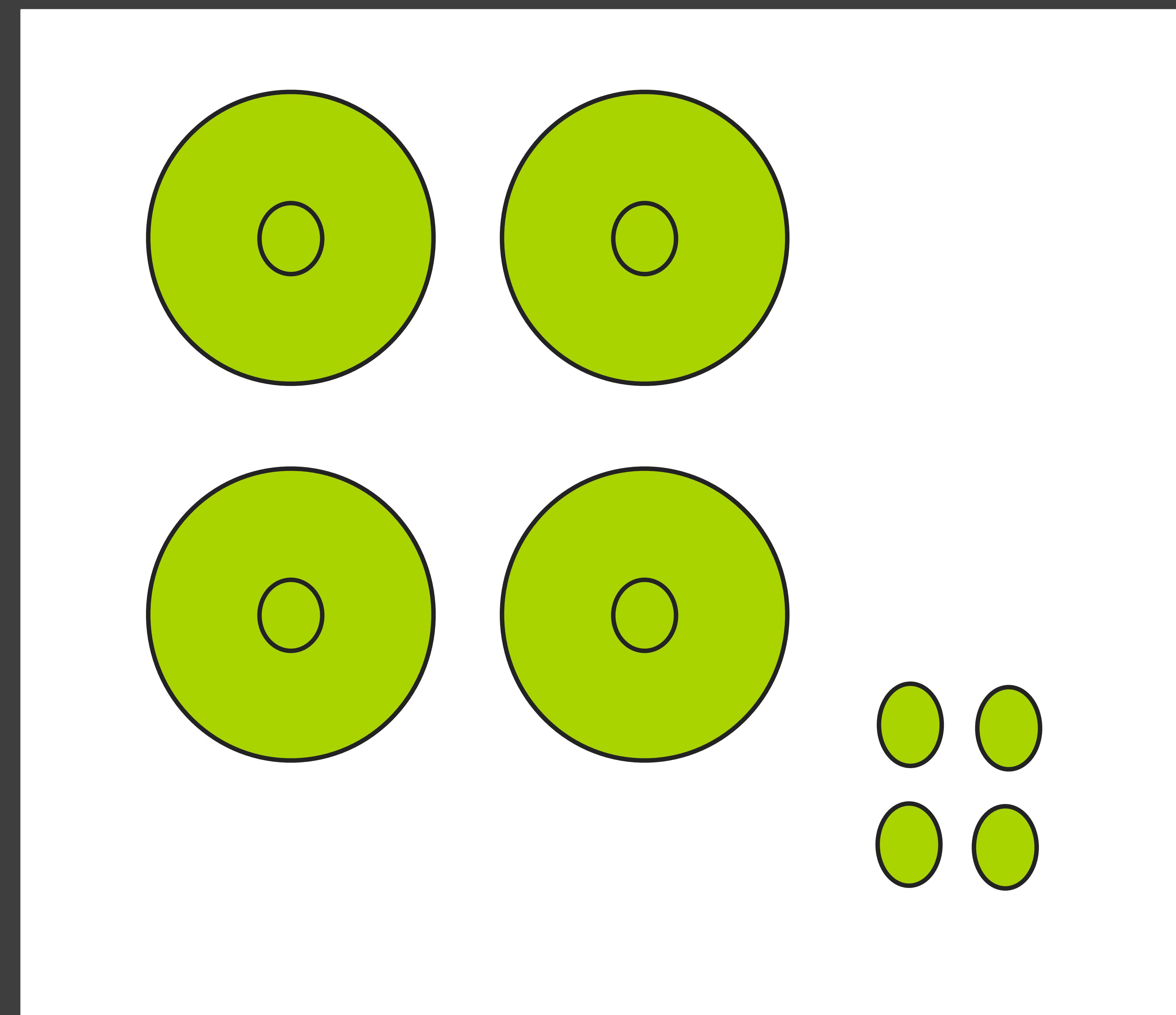


Image Courtesy Wikipedia: http://en.wikipedia.org/wiki/File:Gas_stove.jpg

Clear mapping between control + function





Example (good)

Mercedes S500 Car Seat Controller

Gulfs of execution and evaluation

How might we improve the measuring cup?


OXO
ml
500
450
400
350
300
250
200
150
100
50
OXO
cups
ml

The Gulf of Execution: How do you *do*?

The Gulf of Execution: How do you *do*?

- How do I add more water to the measuring cup?
- How do I remove water?

The Gulf of Evaluation: How do you *know*?

The Gulf of Evaluation: How do you *know*?

- How much water is in the measuring cup now?

The making of gulfs. How easily can someone:

- Determine the function of the device?
- Tell what actions are possible?
- Determine mapping from intention to physical movement?
- Perform the action?
- Tell what state the system is in? / if it's in desired state?
- Determine mapping from system state to interpretation

Questions from Don Norman, *The Design of Everyday Things*

To reduce the gulfs, provide...

- Visibility (perceived affordances or signifiers)
- Feedback
- Consistency (also known as standards)
- Non-destructive operations (hence the importance of undo)
- Discoverability: All operations can be discovered by systematic exploration of menus
- Reliability. Operations should work. Period. And events should not happen randomly.

Source: Donald A. Norman and Jakob Nielsen, ACM Interactions, 2010

Courtesy Bill Moggridge, IDEO

Direct manipulation

Act directly on the object of interest

indirect:

Act directly on the object of interest

direct:

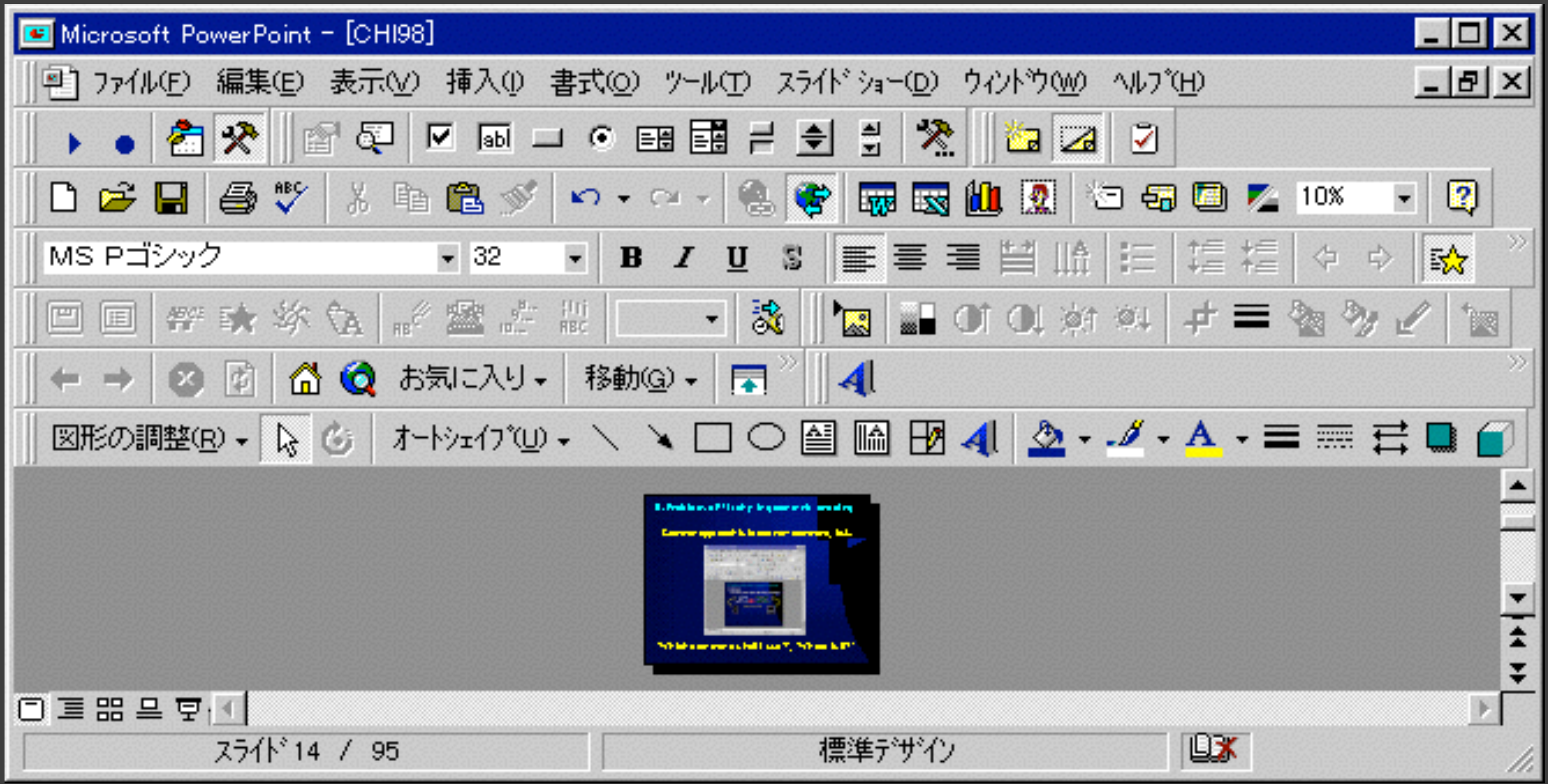
Direct manipulation

- Immediate feedback on actions
- Continuous representations of objects
- Leverage metaphor

COMMAND LINE v. GUI

Principle	Command Line	GUI
Visibility		
Feedback		
Consistency		
Non-destructive		
Discoverability		
Reliability		

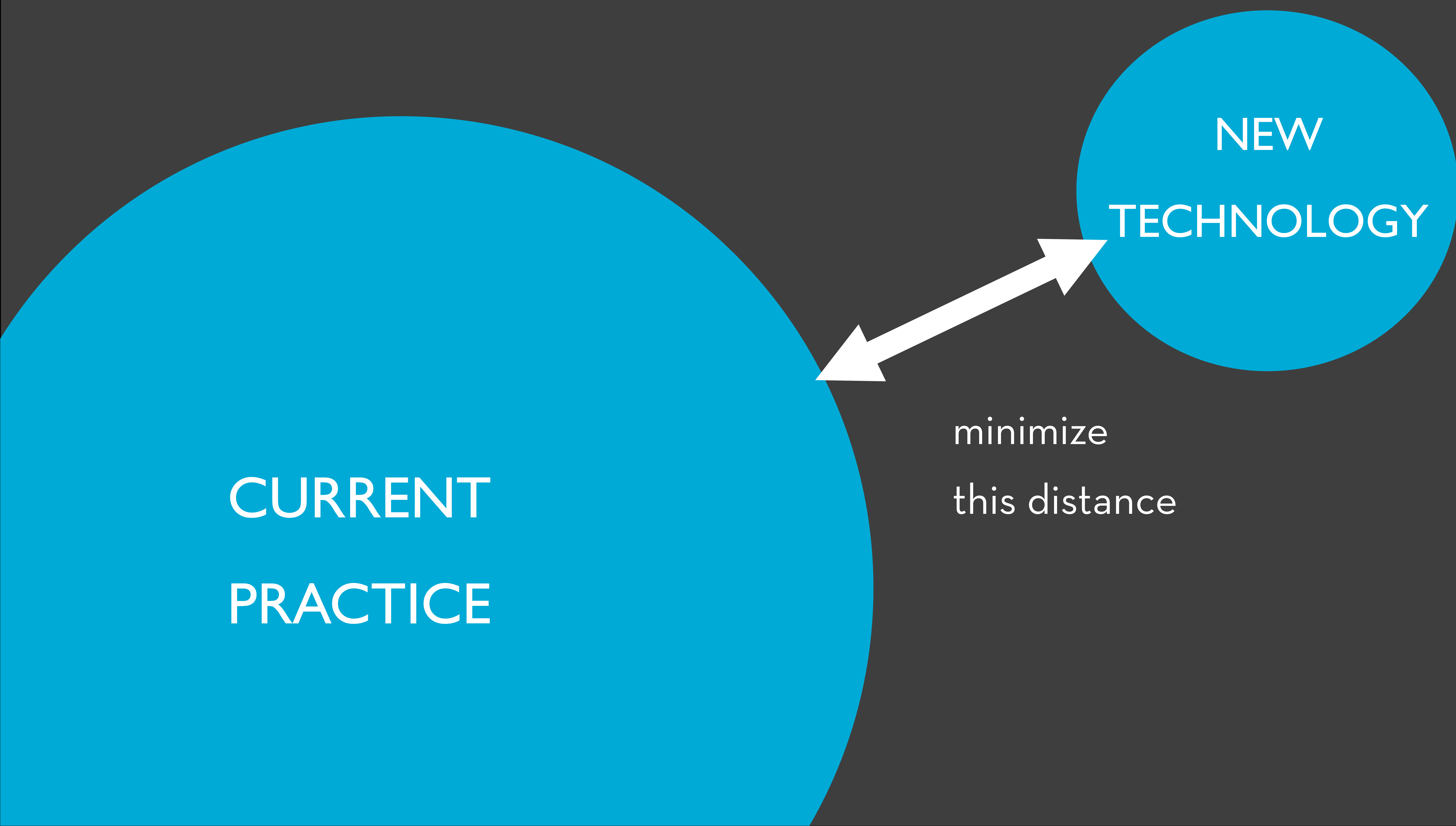
Successful Indirection?



courtesy of Takeo Igarashi

"If technology is to provide an advantage, the correspondence to the real world must break down at some point."

- Jonathan Grudin


NEW
TECHNOLOGY
minimize
this distance
CURRENT
PRACTICE

Final Scratch

Externalizing cognition

We need two volunteers.
One stays, one goes outside.

Let's play number scrabble

- Two players
- Numbers available: 1, 2, 3, 4, 5, 6, 7, 8, 9
- Players draw alternately, without replacement
- Win if three of your numbers add up to 15

Let’s play number scrabble

- X takes 8
- O takes 2
- X takes 4
- O takes 3
- X takes 5

What should O do?

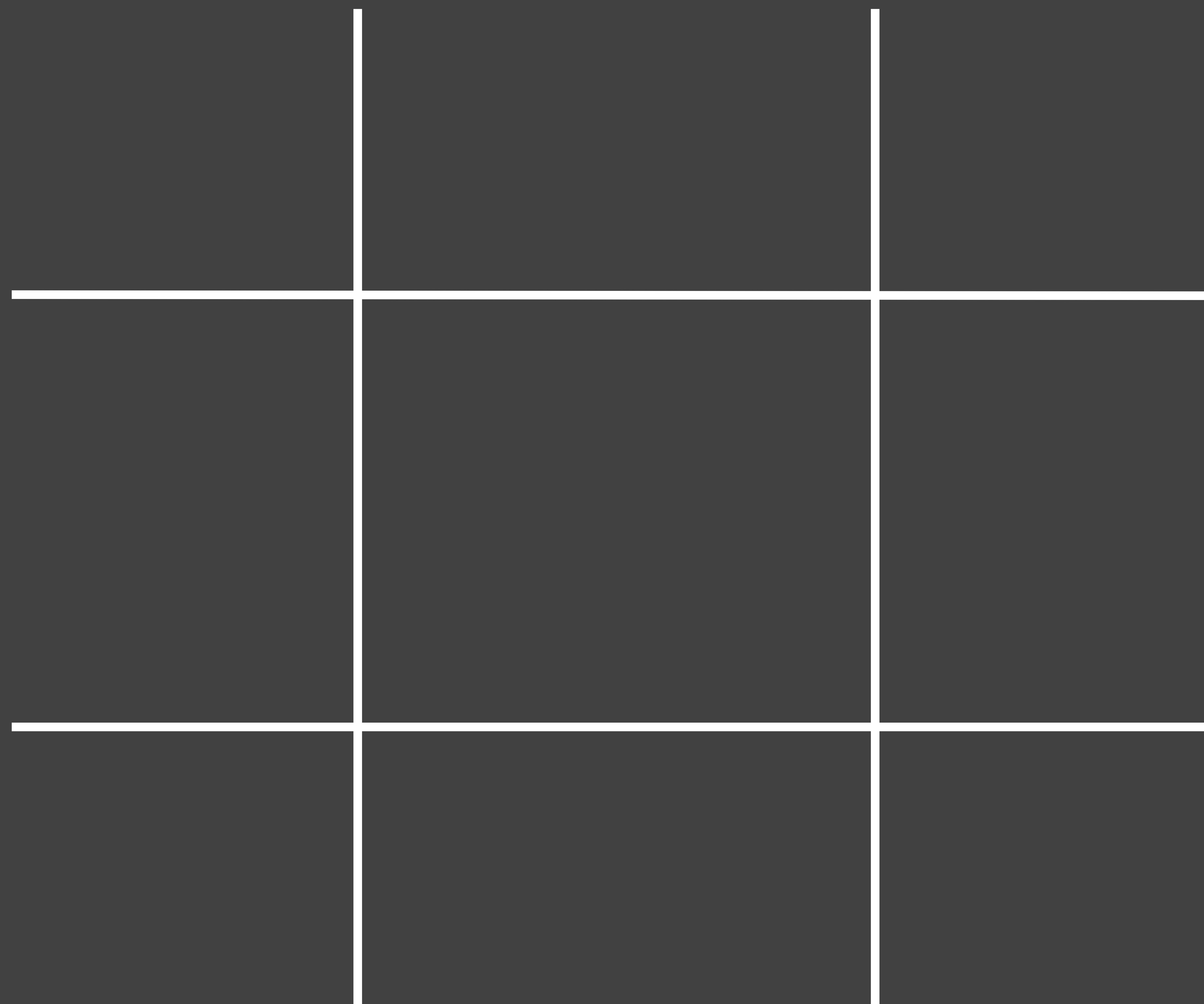
OK, go outside. Don’t talk to your partner. We’ll get them in a second.

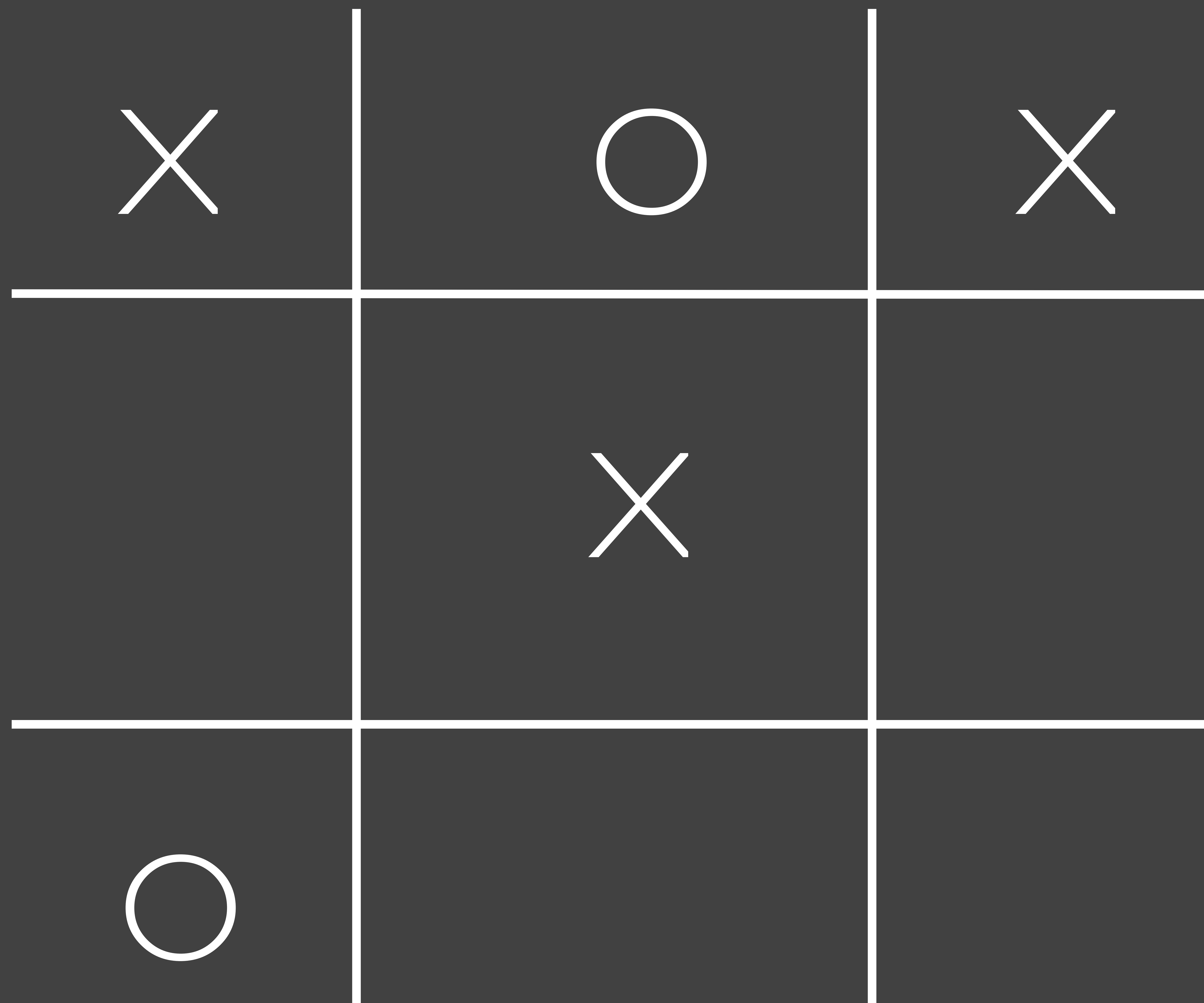
We'll encode this game visually

4	9	2
3	5	7
8	1	6

Let’s go get Player Two.

Tic-Tac-Toe: You are Player O.



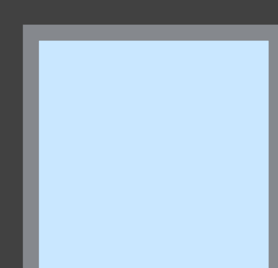


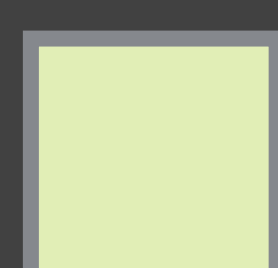
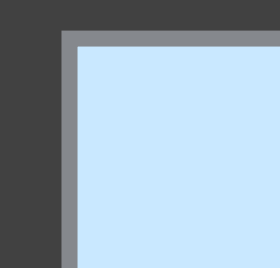
The Color Puzzle

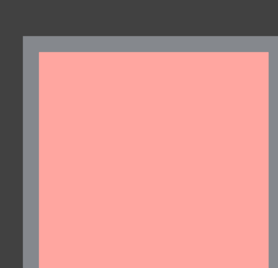
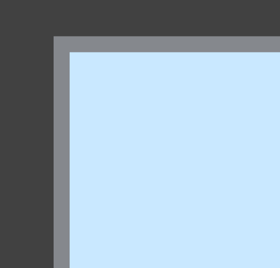
goal Put all the colors in one bin

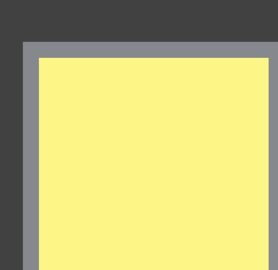
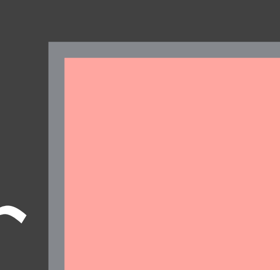
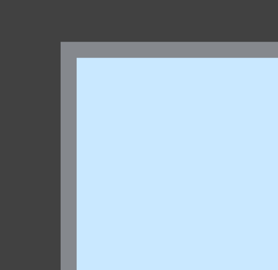
rule 1 Only one color can be transferred at a time

rule 2 Colors can only be moved if certain properties hold:

 can only be put in an empty bin

 can be put in empty bins or bins with 

 can be put in empty or  or 

 can be put in empty or  or  or 

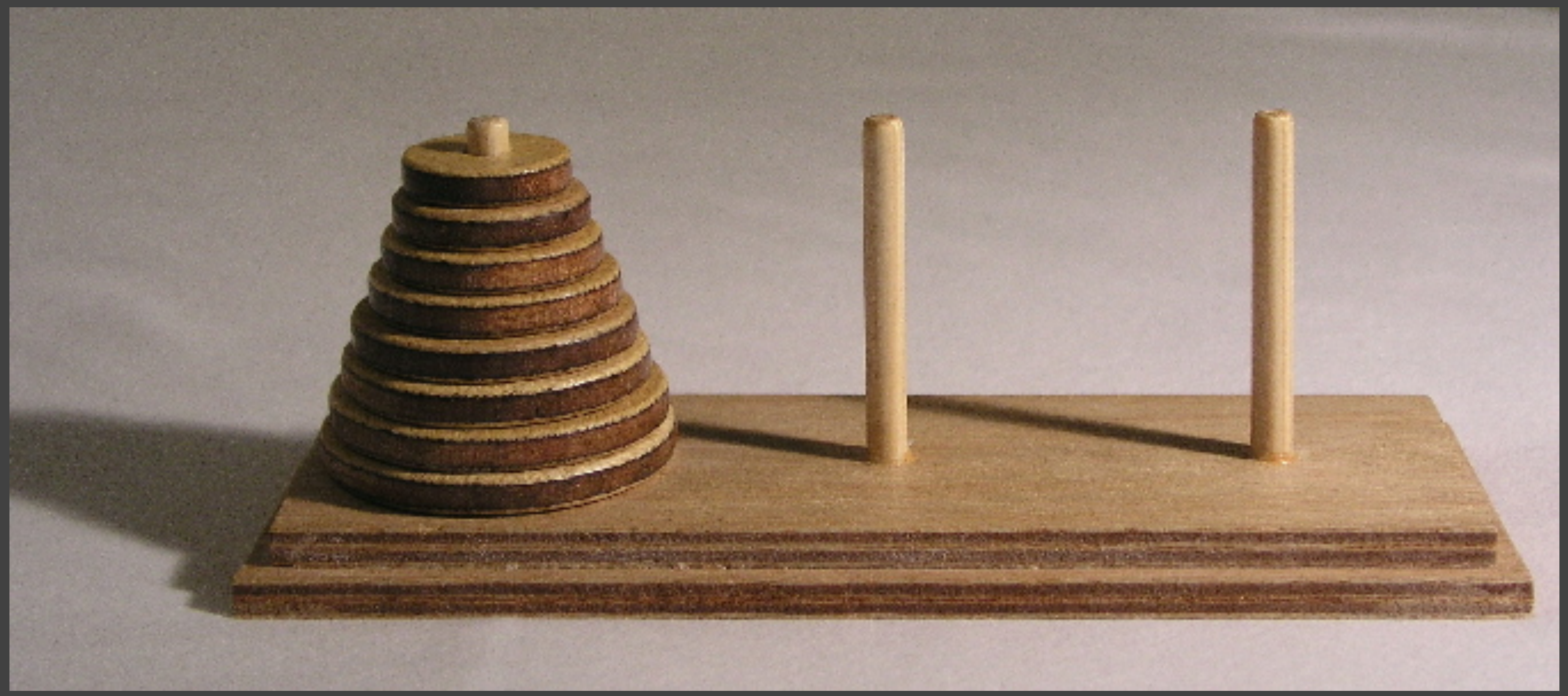
The Towers of Hanoi Puzzle

goal Put all the rings on one peg

rule 1 Only one ring can be transferred at a time

rule 2 A ring can only be transferred to a peg on which it will be the smallest

rule 3 Only the smallest ring on a peg can be transferred to another peg



Anscombe's Quartet

Set A X	Set A Y	Set B X	Set B Y	Set C X	Set C Y	Set D X	Set D Y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.1	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.1	4	5.39	19	12.5
12	10.84	12	9.11	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

Summary Statistics

$u_X = 9.0$ $\sigma_X = 3.317$

$u_Y = 7.5$ $\sigma_Y = 2.03$

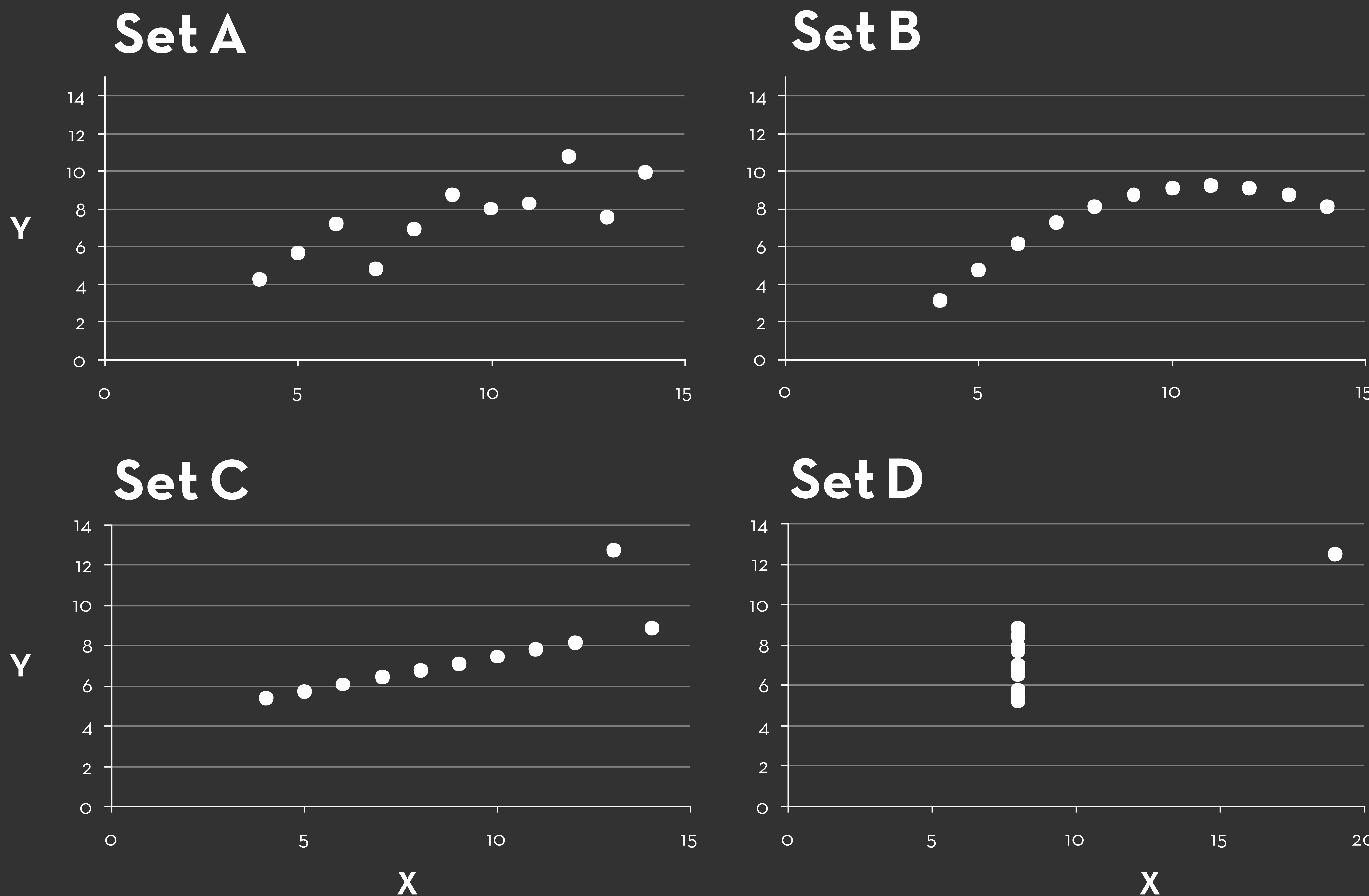
Linear Regression

$Y = 3 + 0.5 X$

$R^2 = 0.67$

[Anscombe 73]

courtesy of Jeff Heer



courtesy of Jeff Heer

[Anscombe 73]

Problem Solving as Representation

> "Solving a problem simply means representing it so as to make the solution transparent"
>
> —Herbert Simon, The Sciences of the Artificial

Naturalness Principle

- Experiential cognition is aided when the properties of the **representation** match the properties of the **thing** being represented

source: Don Norman, Things that Make Us Smart

Offloading Working Memory

e.g., Getting Things Done

Proteus Ingestable Networked Pill

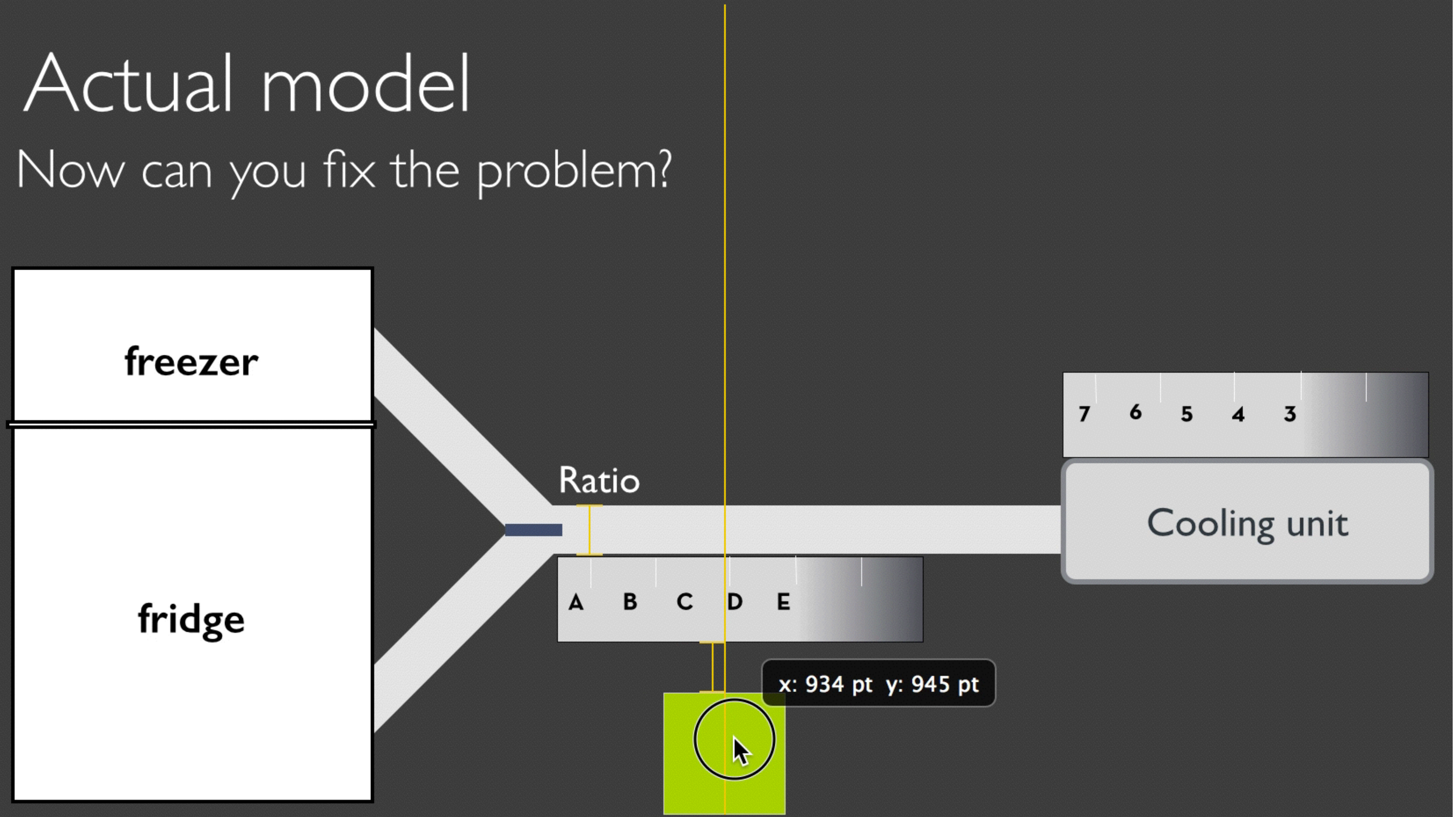
- Sensor and transmitter encapsulates pill
- Stomach acid is part of battery
- Transmits pill
  --> patch
  --> iPhone
  --> Internet

Images courtesy of Proteus Biomedical

Offloading Computation

Actual model

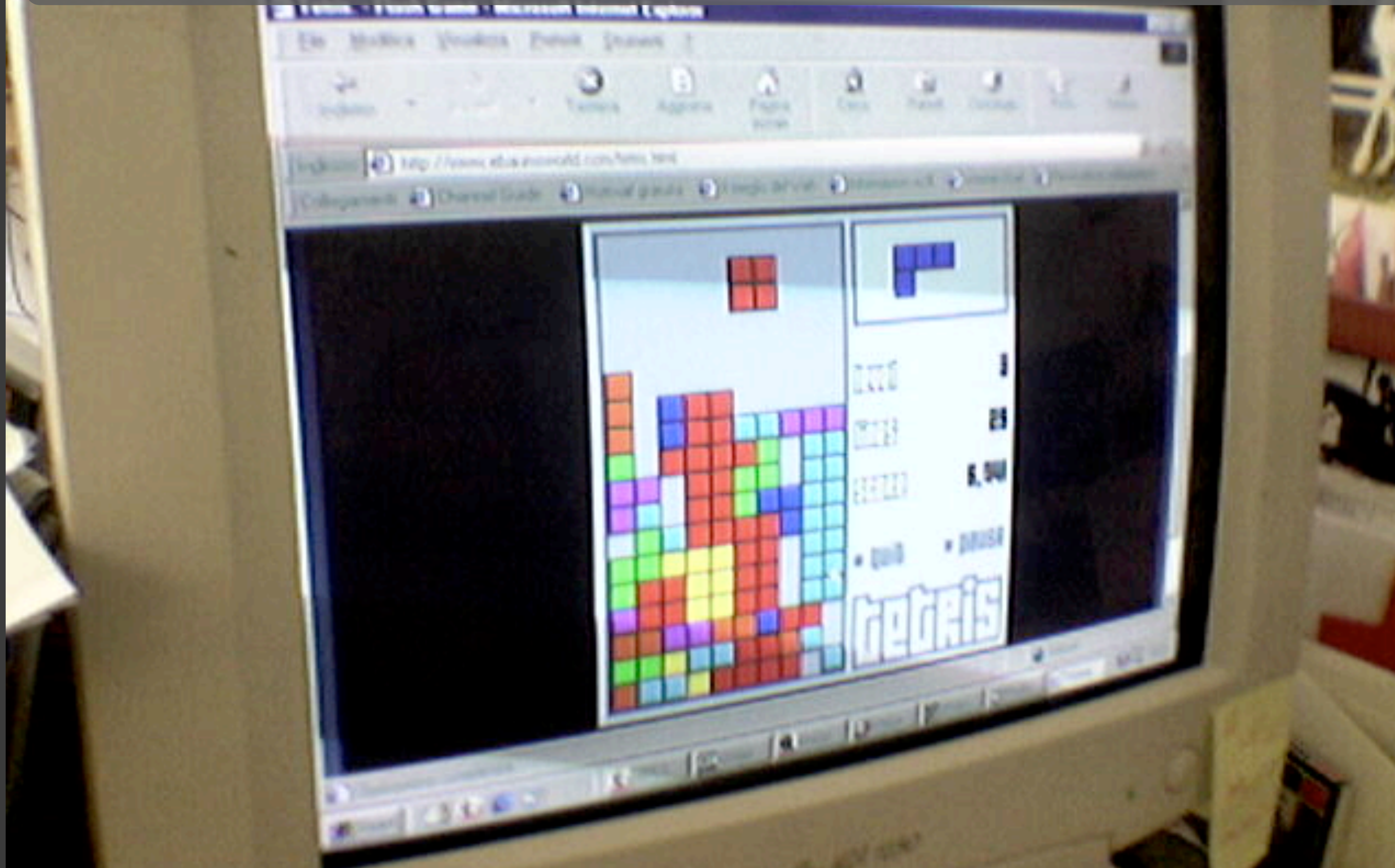
Now can you fix the problem?



When interfaces help people distribute cognition, it can...

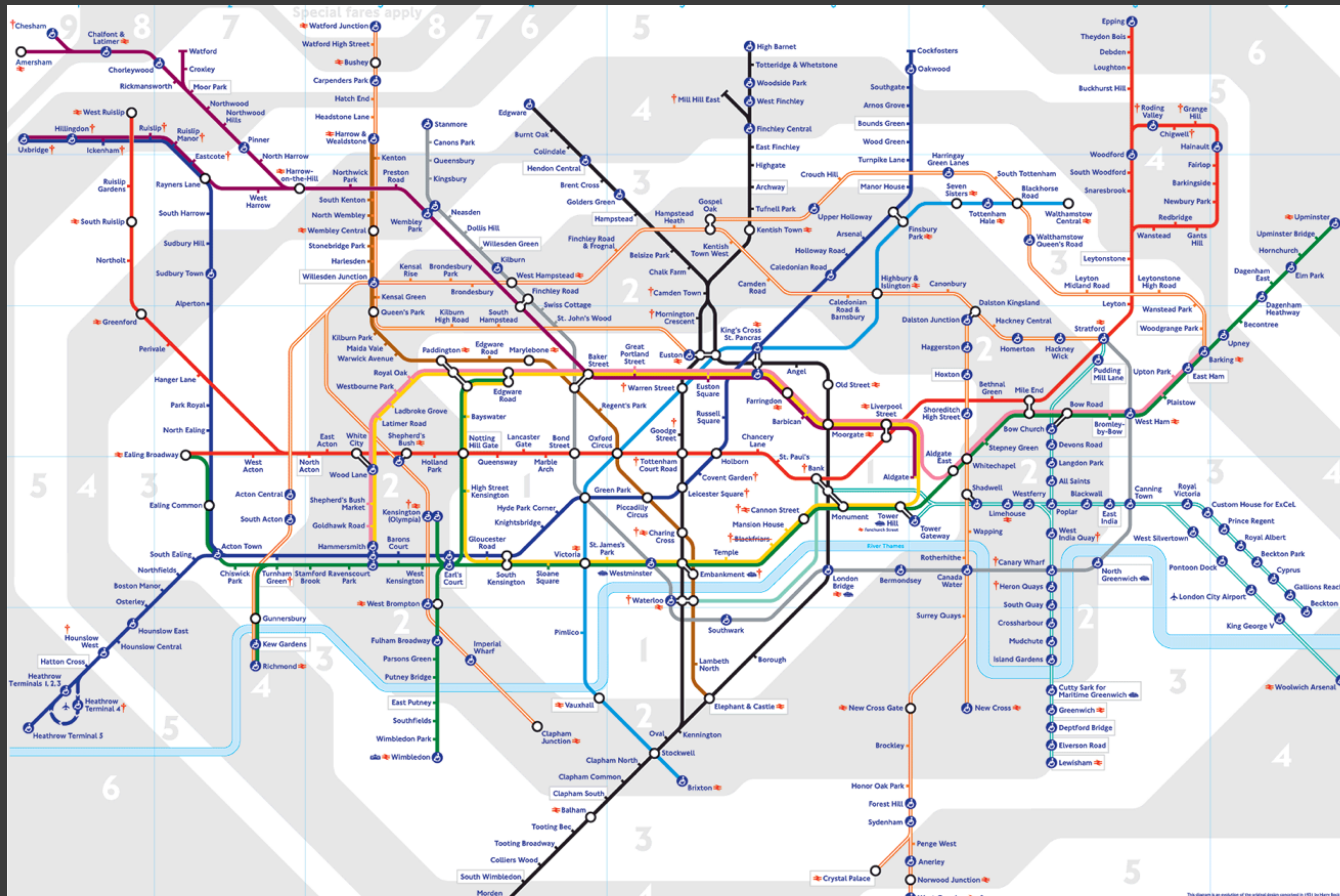
- Encourage experimentation
- Scaffold learning and reduce errors through redundancy
- Show (only) differences that matter
- Convert slow calculation into fast perception
- Support chunking, especially by experts
- Increase efficiency
- Facilitate collaboration

external feedback: cheap experimentation



Kirsh and Maglio

London Underground



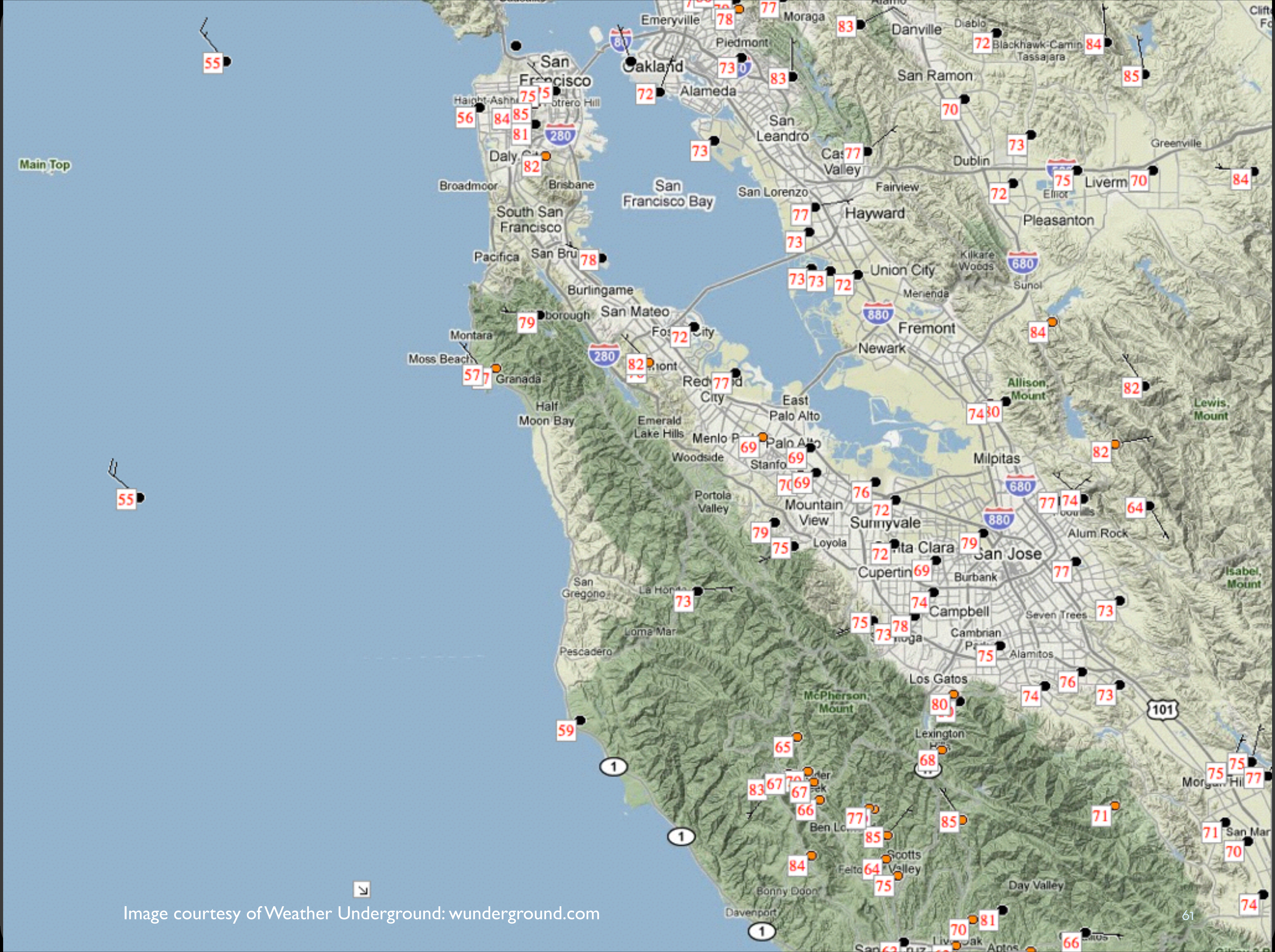
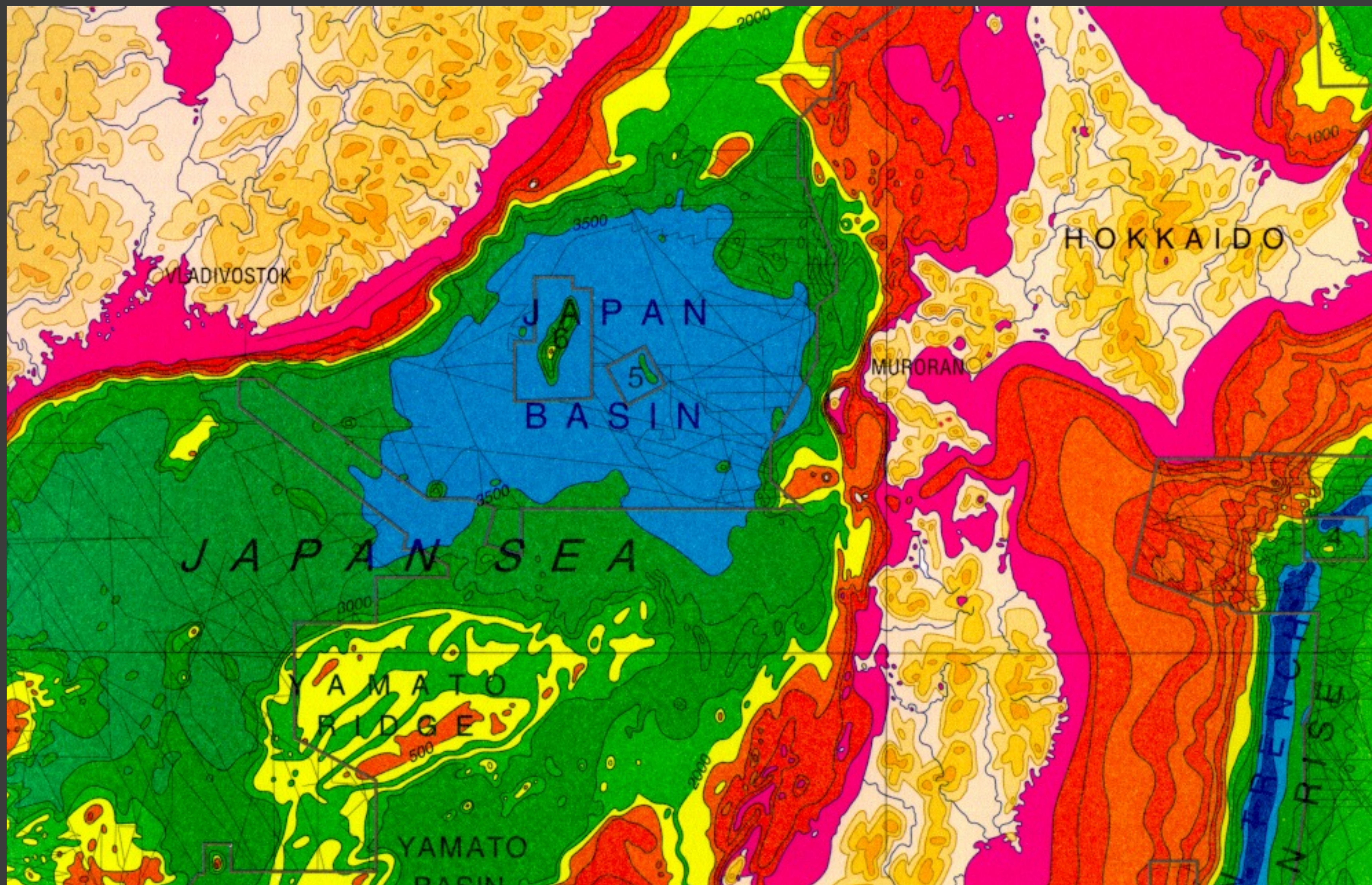
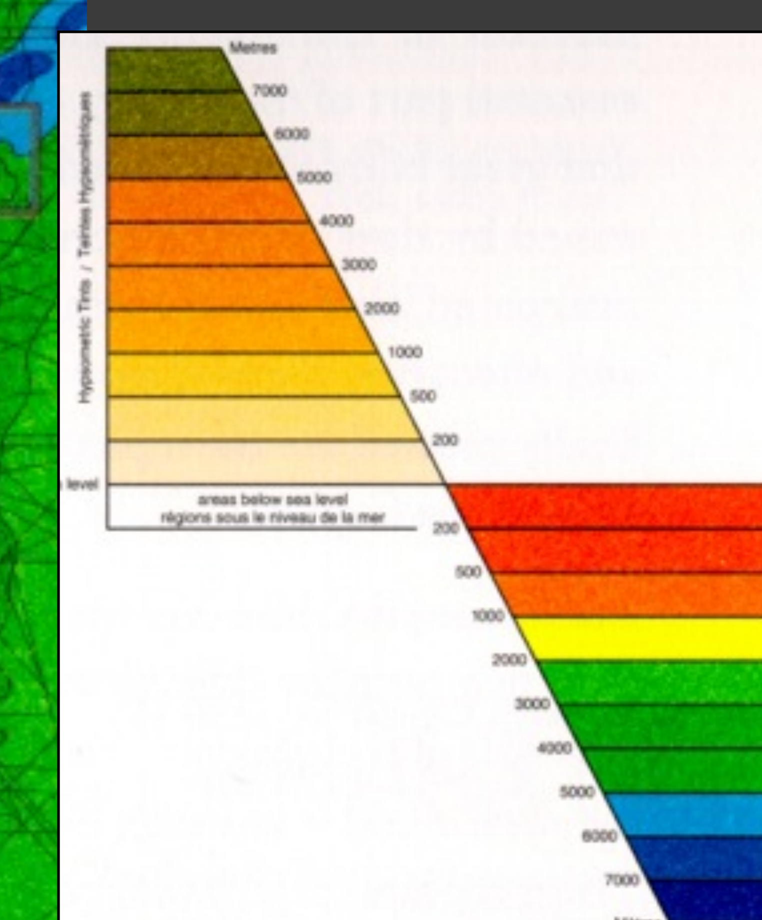


Image courtesy of Weather Underground: wunderground.com

Color: Edward Tufte





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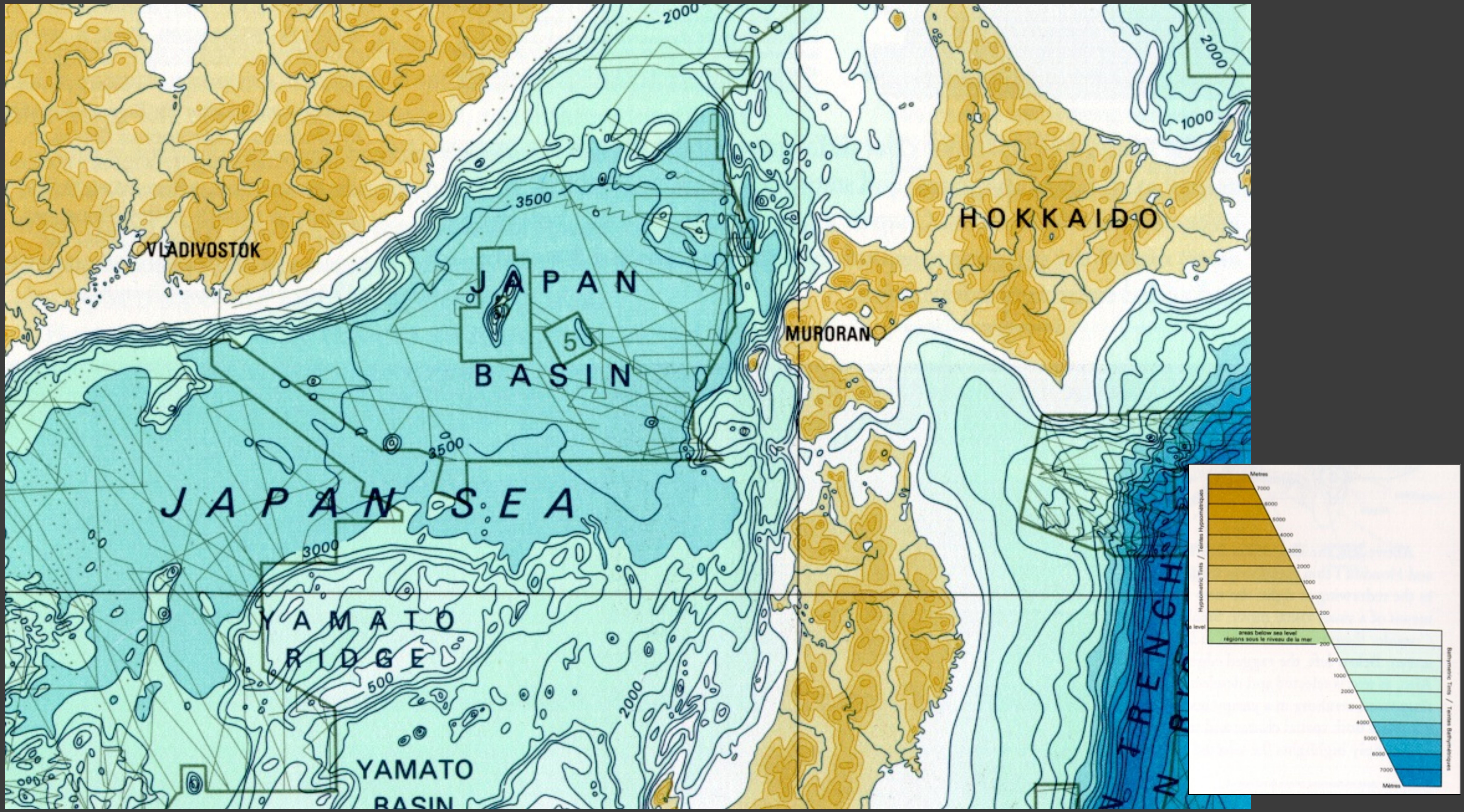

Chase and Simon, 1973:
Experts learn to "chunk" visual stimuli

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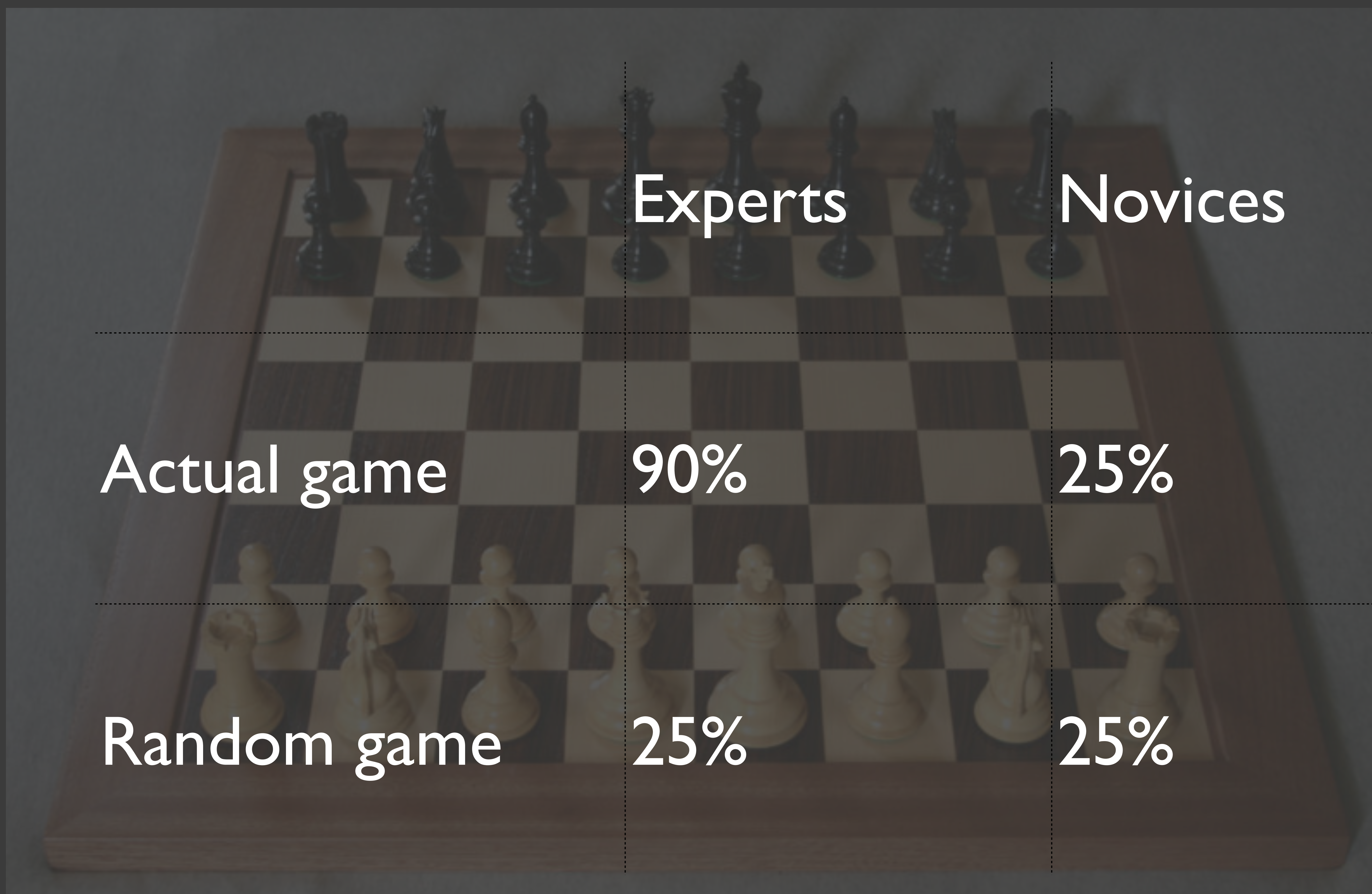
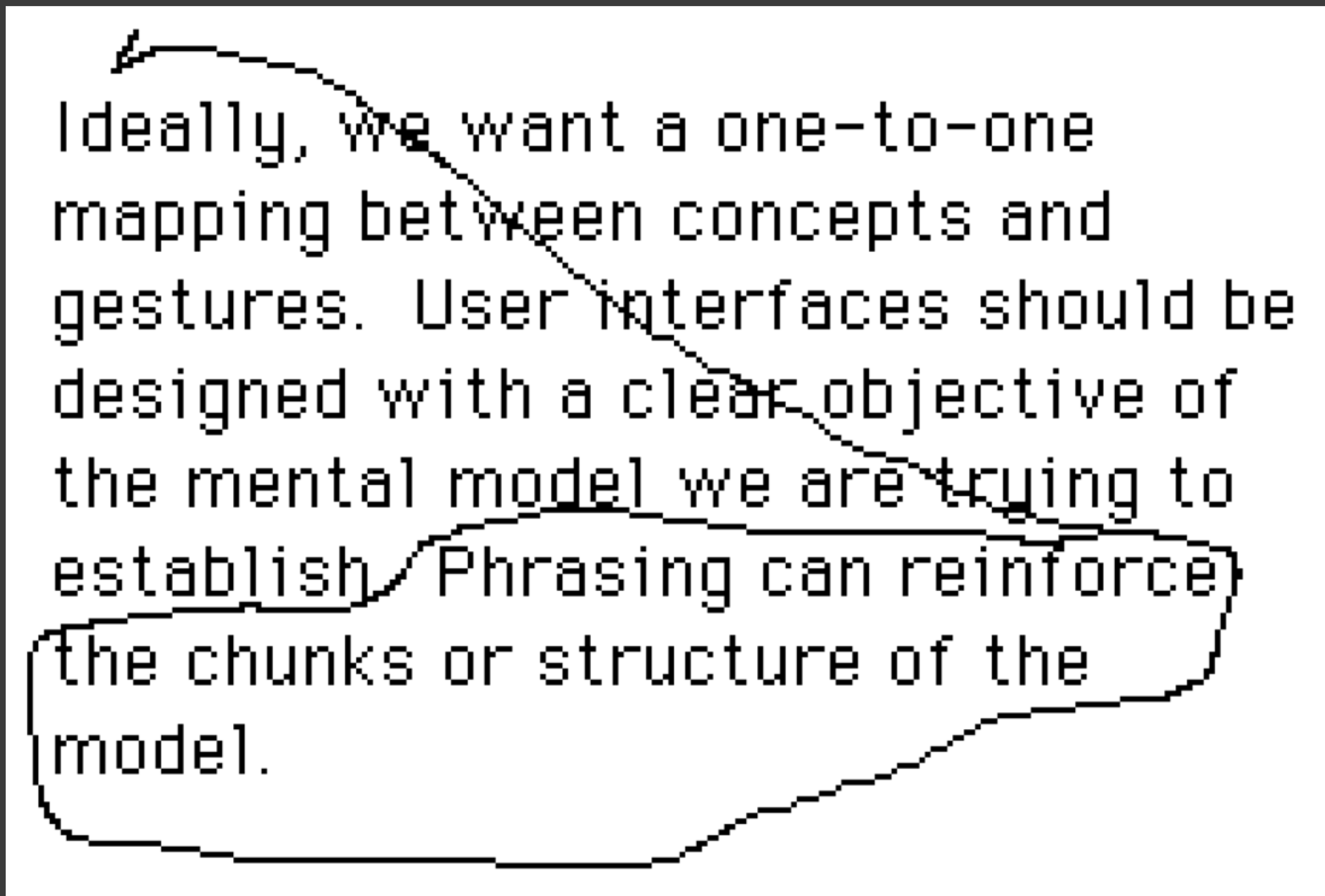


	Experts	Novices
Actual game	90%	25%
Random game	25%	25%

Chunking in Interfaces



How a Cockpit Remembers its Speed

Ed Hutchins

Worth 10,000 Words?

Jill H. Larkin, Herbert A. Simon, Why a Diagram is (Sometimes) Worth Ten Thousand Words

Informational Equivalence

Informational Equivalence
!=
Computational Equivalence

Jill H. Larkin, Herbert A. Simon, Why a Diagram is (Sometimes) Worth Ten Thousand Words